

hybrid combinations of reflective and dichroic polarizers, as described in U.S. Pat. No. 6,096,375. Dichroic polarizer types include H type and K type. Both H and K types were invented by Land and Rogers, and are described in U.S. Pat. Nos. 2,173,304; 2,255,940; and 2,306,108. H polarizers are used in many commercial applications, including virtually all current LCD displays. H polarizers are made by linear orientation (stretching) of a polyvinylalcohol (PVA) film, the surface of which is then imbibed with an iodine solution which forms the required chromophores. A boron complex is then used to stabilize the coating. Sheets of cellulose triacetate (CTA) are then laminated on both sides of the film to protect the relatively vulnerable polarizing layer. K polarizers also start with a PVA sheet, but the PVA molecular structure of linked $\text{H}-\text{C}-\text{H}$ and $\text{H}-\text{C}-\text{OH}$ molecules are selectively dehydrated to form a polyvinylene of linked HC molecules. Sufficiently long, oriented chains of the HC structure absorb light in the visible spectrum.

[0035] The molecular structure of K polarizers are more stable than H polarizers, so K polarizers are more robust for general use issues including temperature range. In spite of these advantages, K polarizers have not gained wide commercial use due to problems including cost, polarizing efficiency, and lack of absorbance in the red region of crossed K polarizers. These disadvantages are balanced however, by the K polarizer's particular advantages in areas that are uniquely important for touch screen applications, including resistance to degradation by flexing, and resistance to degradation by crushing pressure of a stylus tip, and compatibility with chemicals such as acrylics used in hardcoats and with the chemicals used in PSA's (pressure sensitive adhesives).

[0036] Polarizer touch screens are used to great advantage on LCD displays. The upper polarizer required by an LCD may be laminated with the topsheet of the touch screen **8**, rather than being mounted on the top glass substrate **16** of the LCD. The touch screen may then be placed over the LCD display, or alternatively the touch screen substrate **4** may be eliminated, and transparent conductor **1** may be coated directly onto the LCD substrate **16**, so the LCD substrate **16** serves as the substrate of the touch screen. This fully integrated touch screen/LCD configuration is possible only if the top LCD polarizer is moved to the topsheet **8**.

[0037] There are several advantages of such a polarizer touch screen and LCD combination. The optical efficiency may be improved, e.g., ambient light reflections can be significantly reduced. The structure allows omission of the touch screen substrate, with the topsheet mounted directly on the LCD. This reduces thickness and weight. Cost may be minimized because of reduced components, and because integration may be done as part of the LCD manufacturing process.

[0038] A preferred embodiment of the topsheet structure **80** is shown in FIG. 4. PET is used for the support layer **82**. PET is lower in cost than polycarbonate. PET is proven structurally and optically appropriate for the topsheet application, and it is available in thinner sheets than polycarbonate. Optically isotropic polycarbonate cannot be made by drawing the material into sheets. This limits the minimum thickness of polycarbonate sheets to the range of 0.010 inches, which is greater than the optimal topsheet thickness of 0.005 to 0.008 inches. Polycarbonate is also more expensive than PET.

[0039] Though any polarizer **84** may be laminated to the PET layer, the preferred polarizer material is a K type polarizer. 3M Optical Systems Division in Norwood, Mass., formerly a division of Polaroid, sells a commercially available K polarizer known as "KE".

[0040] Optically isotropic hardcoat material is used for hardcoat **86**. Cured acrylic hardcoat materials such as the brand name Terrapin from Tekra Advanced Technologies Group in Berlin, Wis. have sufficiently low birefringence to qualify for this purpose.

[0041] An adhesion promoter **83** may be used to improve the bond between the polyvinylene based K polarizer and the acrylic hardcoat **86**. It was found that silane primer vinyltrimethoxysilane, $[\text{Si}(\text{OCH}_3)_3]$ applied to the polarizer surface immediately prior to hardcoating, provided sufficient adhesion to withstand the demanding requirements of a touch screen. The primer that was found best is made by Witco of Greenwich, Conn., USA under the brand name Silquest A-171. K polarizers are sufficiently chemically stable to tolerate application of the silane adhesion promoter without degrading optical performance of the polarizer.

[0042] Second hardcoat **88** may be applied to the touch surface of support layer **82**. Topsheet structure **80** comprising support layer **82**, polarizer **84**, adhesion promoter **83** and first hardcoat **86** is vacuum sputter coated with conductive coating **90**. The design of topsheet structure **80** allows it to withstand the temperatures and high vacuum environment of the sputter coating process, as well as vacuum plasma etching process. Thin film metal oxide layer **92** may be applied to conductive coating **90**. Thin film metal oxide layer **92** may be a multi-layer structure and may be useful as an anti-reflective stack.

[0043] A method **100** for manufacturing a topsheet with a polarizer layer is shown in FIG. 5. Method **100** includes the steps of providing a support layer having a touch surface and a second surface opposite the touch surface, step **102**, laminating a polarizer, having a first surface and a second surface, to the second surface of the support layer, step **106**, and coating the second surface of the polarizer with a conductive layer, step **116**. Applying a first hardcoat layer to the polarizer, step **110**, may be done prior to coating step **116**. Applying an adhesion promoting agent to the polarizer, step **108**, may be done prior to applying step **110**. After applying step **110**, plasma etching of the hardcoat layer, step **112**, may be performed. Applying a thin film metal oxide layer, step **114** may be performed before coating step **116**. Step **114** may be performed more than once so that a multi-layer anti-reflective stack is formed. Applying a second hardcoat layer to the touch surface of the support layer, step **104**, may also be performed.

[0044] The improved topsheet of this invention may be used to advantage in several different configurations. These include a resistive polarizer touch screen overlaid on an LCD; a resistive polarizer touch screen, laminated to an LCD; and a fully integrated LCD and resistive polarizer touch screen. These improved configurations can reduce optical reflectance of the touch screen by 15% to 30% while reducing thickness of the touch screen by as much as 85%.

[0045] While polarizer touch screens can be used to greatest cost advantage on LCD's, they are also useful with any type of display including CRT's, OLED's, and plasma